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MOVEMENTS, HABITAT AND FORAGE USE OF REINTRODUCED DESERT BIGHORN SHEEP

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Final Report

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INTRODUCTION

Desert bighorn sheep historically occurred in the Virgin and Beaver Dam Mountains, Arizona (Morgart and Krausman, 1981). There have been recent sightings of sheep in these ranges but there has not been a reproducing population in the area since the 1940's. Desert bighorn sheep numbers and range have declined in North America during the past 200 years (Buechner, 1960). The decline in the Virgin Mountains may have been caused by illegal hunting and disease from livestock (Morgart and Krausman, 1981).

The Bureau of Land Management (BLM) and the Arizona Game and Fish Department (AGFD) compiled the Black Rock Habitat Management Plan in 1976 to "provide suitable habitat in the Virgin Mountains for the reintroduction of desert bighorn sheep" (Morgart and Krausman, 1981). In January 1979, a 283-ha enclosure was constructed in Hedricks Canyon on the western slopes of the Virgin Mountains (T40N, R15W, sections 23, 24, and 25)(Fig. 1). From 12-14 November 1979, 12 bighorn sheep, (2 adult rams, 1 yearling ram, 7 adult ewes, and 2 yearling ewes) were captured in the Black Mountains, Arizona and released in the enclosure. Bighorn sheep capture and transplant procedures are described by deVos and Remington (1981). This enclosed population grew to 25 animals within 2 years.

In November 1981, 41 bighorn sheep were captured in the Black Mountains and released at two sites: Sullivans Canyon and Buck Springs, north and south of the enclosure, respectively (Fig. 1). Twenty of these sheep were instrumented with radio collars. Sheep were placed in burlap covered holding pens overnight to recuperate after capture. Pens were opened the following morning to allow sheep to leave on their own accord. On 18 January 1982, 21 of the 25 enclosure sheep were

removed from the enclosure, resulting in 62 free-roaming bighorn sheep in the Virgin Mountains, 30 with radio collars (Appendix 1).

The objectives of this study are to compare the initial movements, mortalities, and productivity of released sheep to evaluate the 2 release techniques, and determine habitat and forage use of bighorn sheep in the Mohave Desert in Arizona. Rowland and Schmidt (1981) reviewed 13 sheep transplants using enclosure and direct releases. The Virgin Mountain sheep reintroduction is the only situation where both techniques are being used at the same time and place.

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STUDY AREA.--The study area includes portions of the Virgin and Beaver Dam Mountains 7 km east of Beaver Dam, Arizona. These mountains extend from Clark County, Nevada into Mohave County, Arizona, ending in Washington County, Utah (Fig. 1). Elevations range from 510 m at the Virgin River Gorge (VRG) to 2,400 m on Mt Bangs. Two major soil associations on the study area are Tortugas-Welring rock outcropping in the north and Barkerville-Gaddes rock outcropping in the south. The western portion of the Virgin and Beaver Dam Mountains has a much steeper relief than the east. Vertical cliffs and 100% slopes are common in the Virgin River Gorge. For more information on the geology of the Beaver Dam and Virgin Mountains, see Moore (1972).

The lower mixed Mohave desert shrub type (LMM) makes up approximately 33.5% of the study area. Elevations in LMM range from 610

in the VRG to 1,281 m in Hedricks Canyon (Fig. 1). LMM is found on the lower elevations north of Hedricks Canyon in the Virgin and Beaver Dam Mountains. Major vegetation includes green ephedra (Ephedra viridis), mortonia (Mortonia utahnensis), creosotebush (Larrea tridentata), white ratany (Krameria gravi), white bursage (Ambrosia dumosa), and snakeweed (Gutierrezia sarothrae).

Upper mixed Mohave desert shrub (UMM) is found at intermediate elevations from the top of Figure 4 Canyon south to the Nevada-Arizona border. UMM represents approximately 38% of the study area. In the southern portion of the study area UMM replaces LMM at the lower elevations. Major vegetation consists of yucca (Yucca utahnensis), turpentine-broom (Thamnosoma montana), green ephedra, Nevada ephedra (E. nevadenensis), encelia (Encelia frutenscens), flattop buckwheat (Eriogonum fasciculatum), and snakeweed.

Creosotebush-bursage flats (CBB) make up approximately 8.4% of the study area. CBB are located below the western slopes of the mountains and east of the VRG. Major vegetation consists of creosotebush, white bursage, and buckhorn cholla (Opuntia acanthocarpa).

Riparian areas (RIP) are located along the Virgin River and in major canyon drainages. RIP represent only 3% of the study area. Major vegetation includes desert willow (Chilopsis linearis), rabbit brush (Chrysathamnus nauseosus), sweetbush (Bebbia juncea), burro brush (Hymenoclea salsola), desert almond (Prunus fasciculata), turpentine-broom, green ephedra, creosotebush, and snakeweed.

The blackbrush type (BB) is found scattered through approximately 6.8% of the study area. BB is found in pockets in the VRG, upper slopes of the Beaver Dam Mountains, and the lower slopes near Elbow and Hatchet Canyons (Fig. 1). Blackbrush (Coleogyne ramosissima) is the major

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overstory species, making up over 90% of the total vegetative cover. Other species consist of green ephedra and turpentine-broom.

The pinyon-juniper type (PJ) is found at the higher elevations above 1,464 m. More extensive stands start above Hedricks Canyon and continue into the Virgin Mountains in Nevada. Major vegetation consists of single-leaf pinyon (Pinus monophylla), alligator juniper (Juniperus osteosperma), and shrub oak (Quercus turbinella). Ponderosa pine (Pinus ponderosa) and Douglas fir (Pseudotsuga manziesii) are found at the higher elevations near Mt. Bangs (Fig. 1).

Temperatures in the area range from 31C in July and August to 8C in December and January. Precipitation falls predominantly from November through March with a 19 cm yearly average (Sellers and Hill, 1972).

The Virgin River flows year round, though intermittently during dry summers. Springs and ephemeral pools provide free-standing water. Catchments were constructed above Figure 4 Canyon and in Hedricks and Frehner Canyons (Fig. 1) by the BLM and the AGFD to provide permanent water.

The entire study area is under the jurisdiction of the Arizona Strip regional office of the BLM. A large portion of the area consists of the Piute Primitive Area. Major land uses on the study area include mining in the 1950's, cattle grazing, and hunting.

METHODS.--Locations of 532 sheep (167 ram groups, 292 ewe groups, and 73 mixed groups) were collected between 23 March and 14 August 1982 and betwen 5 January and 31 July 1983 from ground and aerial locations. Flights were conducted weekly to biweekly to locate all radio collared sheep. A PA-18 Super Cub equipped with the antennae system described by LeCount and Carrell (1979) was provided by the AGFD. Sheep were located

on the ground by using a handheld TR-2 receiver and dipole antenna. All telemetry equipment was provided by Telonics, Inc., Mesa, AZ. Locations were recorded using the Universal Transverse Mercator grid system (UTM) and USGS Topographic maps. Data recorded from each ground location included individual identification, groups size, behavior (feeding, bedding, moving, social interacations), major over and understory vegetation, topography, and weather conditions. Initial and established movements and areas used were compared by using the Mann-Whitney test for independent samples (Conover, 1971) and paired t-test (Lentner, 1981). Habitat types were visually delineated. One hundred (0.004-ha) circular plots were run in each of the 6 vegetative types (Brower and Zar, 1977). Analysis by BLM computer provided information on species composition, density, and cover of perennial vegetation.

Availability of different habitat types, slope, aspect, and elevation classes was determined by the non-mapping technique (Marcum and Loftsgaarden, 1980). Eight hundred random UTM grid coordinates were generated (error of estimation = 0.05, alpha = 0.007).

Availability of different habitat variables were compared with sheep use using X^2 analysis (Neu et al., 1974) and G-factor analyses (Sokal and Rohlf, 1980).

Forage selection was determined by microhistological analysis of collected fecal material at the Range Resources Division at the University of Arizona, Tucson (n = 120 samples). Twenty fields were analyzed per slide. Dietary overlap between rams and ewes for winter, spring, and summer were examined by the technique described by Alcoze and Zimmerman (1973). Dietaray overlaps between seasons for rams, ewes, and all sheep were also calculated. Overlap coefficients range from 0 (no overlap in diet) to 1 (total dietary overlap). Values $\geq$ 0.60

indicate significant overlap (Alcoze and Zimmerman, 1973). Simpson's diversity indices were calculated for ewe, ram, and all sheep diets during winter, spring, and summer. For all statistical analyses, $P < 0.05$ was considered significant.

Productivity and mortality were determined by field observations. Use areas were calculated using the minimum polygon method (Mohr, 1947). Individual radio collared sheep are referred to by a three digit radio frequency and cloth collared sheep by a 2 digit ear tag number.

RESULTS AND DISCUSSION.--Movements.--The reintroduced sheep in the Virgin Mountains exhibited the exploratory behavior described by McQuivey and Pulliam (1980) and deVos et al. (1981). Movements from release to first location varied from 2.5 to 6.4 km ($\bar{X}$ = 3.8 km) and 1.6 to 5.7 km ($\bar{X}$ = 3.0 km) for the Sullivans direct-released rams and ewes, respectively. Movements from release site to first location varied from 1.9 to 4.9 km ($\bar{X}$ = 3.7 km) and 1.6 to 5.73 km ($\bar{X}$ = 3.1 km) for the enclosure-released rams and ewes, respectively. There was no difference between the first movement after release for the enclosure-released and Sullivans direct-released sheep ($Z = 0.076$, $P = 0.47$).

The first 5 sheep locations after release were plotted for Sullivans direct-released sheep (12 December 81 to 28 January 82) and enclosure-released sheep (28 January 82 to 13 April 82). Distances between locations were measured in chronological order (release site to location 1, location 1 to 2, . . ., location 4 to 5). The initial movements for Sullivans sheep varied from 0.57-13.39 km as compared to 0.25-14.28 km for the enclosure-released sheep (Table 1). Ram movements ranged from 0.57-6.38 km and 0.25-14.28km for the Sullivans direct release and enclosure release, respectively (Table 1). Ewe movements

ranged from 0.57-13.39 km and 0.3-6.44 km for the Sullivan release and enclosure release, respectively (Table 1).

Initial movements of the Sullivans direct release sheep were larger than those of the enclosure-released sheep ($Z = 2.393$, $P = 0.0084$). Direct released ewes in Sullivans Canyon moved greater distances than enclosure-released ewes ($Z = 2.863$, $P = 0.0021$). Enclosure-released rams moved more than enclosure-released ewes ($Z = 1.843$, $P = 0.0027$). There were no differences between the initial movements of direct released rams and ewes or direct released rams and enclosure-released rams.

The smaller initial movements of the enclosure-released sheep may have been a result of the sheep being familiar with the area outside the enclosure. They were not released into a new area as were the direct-released sheep. Most of the enclosure-released sheep remained in the Hedricks Canyon area for the first month after released. The direct released sheep immediately dispersed from their release site.

Locations 6-10 were plotted for both groups of sheep. Distances between movements of the 2 groups were not significant ($Z = 0.356$, $P = 0.365$). The movements of rams were greater than ewes ($Z = 3.004$, $P = 0.0015$) in Sullivans Canyon. The decrease in the ewes movements may have resulted because 4 out of 5 ewes lambed at this time. There were no significant differences between movements of direct released rams and enclosure-released rams, enclosure-released ewes and direct released ewes, or enclosure-released rams and ewes.

Use areas refer to the home range of the sheep during the first 5 locations and locations 6-10. Initial use areas were plotted for locations 1-5 for direct releases in Sullivans Canyon and enclosure-released sheep and for ewes with and without lambs. Initial use areas

of the Sullivans Canyon sheep were larger than those of the enclosure-released sheep ($Z = 2.38$, $P = 0.01$). Ewes in Sullivans Canyon used larger areas than the enclosure-released ewes ($Z = 2.24$, $P = 0.01$). There were no significant differences between initial use areas of rams and ewes in Sullivans Canyon or enclosure-released rams and ewes. Initial use areas of ewes carrying lambs were not larger than those without lambs.

The initial use areas for all sheep were not significantly larger than the next 5 locations ($t = 1.76$, $df = 14$, $P = 0.051$). Among ewes, the initial use areas for all ewes were significantly larger than the second group of use areas ($t = 2.07$, $df = 7$, $P = 0.038$). The initial use areas of all rams were not larger than the second group of use areas ($t = 1.27$, $df = 7$, $P = 0.123$).

After release, the direct-released sheep dispersed into more groups initially than the enclosure-released sheep (Table 2). During the first 3 flights, direct-released sheep were located in small groups of 1-3 animals and enclosure-released sheep were in groups of 1-8 animals. On the third flight, enclosure-released sheep were located in 10 groups; six of these were only 0.40-0.48 km from another group. After the third flight, sheep from Sullivans Canyon and enclosure releases began intermixing.

The Direct Release

Sullivans Sheep.--As a group, sheep in Sullivans Canyon moved farthest from their release site during exploratory movements. Two sheep (ewe 670 and ram 870) moved long distances within a few weeks of release on 11 November 1981. Ewe 670 was not found until 30 December. She had moved to Lizard Point, 17 km east of the release site (Fig. 1).

She lambed and remained in the area until July 1982; thereafter she used the Purgatory Canyon area (Fig. 1). Ram 870 was found on Bunkerville Ridge, Nevada, 40 km from the release site, on 23 March 1982 (Fig. 1). He moved east to the Hatchet Canyon area (Fig. 1) where 5 adult ewes were present during the 1982 fall-winter breeding season. He then returned to Nevada for the duration of the study and was seen with Nevada sheep on 3 occasions. Ram 840, 1 1/2 years old at release, moved about a great deal during the study. He never remained in any particular area as other sheep did. He continually moved between the VRG, Purgatory, and Hedricks Canyons (Fig. 1). Ewe 700 moved 13.1 km to Black Rock Gulch near Pocket Hill after the first flight on 8 December 1981 (Fig. 1). She later joined ewe 820 in the Grey Points-Purgatory Canyon area. Ewe 700 disappeared into the Beaver Dam Mountains, Utah in fall 1982. Her band, 2 ewes and 2 yearlings, were located in the VRG in March 1983. Ewe 14 and her lamb were located in Sullivans Canyon 10.5 m south of the release site during the summer of 1982. Ram 17 was found dead 14 February 1982 in Hatchet Canyon Gorge, 26 km from the release site. The rest of the collared sheep remained within 7 km of the release site in the VRG area during the study.

Buck Springs Sheep.--All Buck Springs radio collared sheep, except for ram 210, remained within 5 km of the release site. Ram 090 moved 3.5 km to Hatchet Canyon Gorge, then moved 7 km north where he was killed by a mountain lion (Felis concolor). Ram 210 moved 19 km east to Sullivans Canyon where he remained until fall 1982. He then moved 12 km to the VRG for the remainder of the study. Two cloth collared sheep (38 and 36) were found in the VRG with Sullivan and enclosure-released sheep throughout most of the study.

Hedricks Canyon.-- Rams and ewes from the enclosure moved into different areas after release. All but 4 were found together on the first flight. The ewes, with the exception of 900 who moved to the VRG, moved into the rugged area between Figure 4 and Hedricks Canyons. The rams moved 3.5 km north to the Figure 4 Canyon-VRG area. Ram 880 was the only enclosure-released sheep to continually make long erratic movements. His initial use area (60 km^2) was almost twice that of any direct-released sheep. When 880's movements are not included in analysis, the initial use areas of the enclosure-released rams are significantly smaller than those of the direct-released rams ($Z = 2.29$, $p = 0.01$).

Immediate dispersal and exploratory movements after direct releases have been observed by Bavin (1980), Ramey et al. (1980), McQuivey and Pulliam (1981), Ravey and Schmidt (1981), and Elenowitz (1982). This may result from stress from human handling (Davis, 1983) or capturing and releasing sheep from different social groups (Ravey and Schmidt, 1981). Sheep were not confined together long enough to develop social ties.

A disadvantage to extensive exploring after a direct release is decreased encounters during the breeding season (Ravey and Schmidt, 1981; Elenowitz, 1982). Sheep dispersing out of an area and not returning do not aid in increasing the transplant population. Ewes 700 and 13 from Sullivans Canyon and their 1982 offspring moved to the Beaver Dam Mountains, Utah in fall 1982 and were not bred. However, ram 870 from Sullivans Canyon briefly returned from Bunkerville Ridge, Nevada to breed the Buck Springs ewes in Hatchet Canyon Gorge. Sheep dispersing individually are also more susceptible to predation (Berger,

1978; Hornocker, 1970). Two sheep from Buck Springs (ewe 020 and ram 090), and a ewe from Hedricks Canyon (911) were killed by mountain lions after moving into a new area alone. However, sheep from Sullivans Canyon, who dispersed farther and in more single animal groups, did not suffer any lion predation. Most of the lion kills occurred at higher elevations, south of the majority of sheep use areas. With the exception of ewe 911 in Hedricks Canyon which was killed in a LMM type, lion kills occurred in the UMM and PJ types. Two sheep, (ewe 911 from Hedricks Canyon and 020 from Buck Springs), were found dead in the bottom of narrow, steep sided canyons.

An advantage to immediate dispersal after release is that sheep explore and become more acquainted with a larger area. Bighorn sheep rarely disperse to new areas. Sheep pass the same home ranges from generation to generation, thus limiting the stimuli to disperse to new areas (Geist, 1967). Whether or not enclosure-released sheep would have moved to some areas cannot be determined. With the exception of ram 880's location in Black Rock Gulch on 13 April 1982, enclosure-released sheep were not found far from their release site without accompanying a direct-released sheep. Ram 840 was the most exploratory of the sheep from Sullivans Canyon. Two-year-old rams such as 880 from Hedricks Canyon and 840 from Sullivans Canyon do move into new areas, only to return if the area is uninhabited by sheep (Geist, 1967, 1971). Enclosure-released rams explored more than enclosure-released ewes. Rams ranged from 1.2 to 20.1 km, whereas ewes remained within 1.2 to 8.9 km of the release site. In groups, rams will exploit new habitats while ewes tend to remain in familiar areas such as lambing areas (Geist, 1971; Dodd, 1983).

Habitat Use.--Habitat use differed significantly from availability ($G = 105.4$, $df = 6$, $P = 0.000$). LMM and BB communities were preferred by all sheep and by rams; ewe and mixed groups preferred only LMM. CBB, RIP, UMM, and PJ communities were used in lower proportions than availability by all groups examined. Disturbed areas (DIS) were used in the same proportion as availability (Table 3).

Although availability of CBB exceeded use, sheep fed on winter annuals during late winter and early spring in this community. Annuals such as red brome (Bromus rubens), plantain (Plantago insularis), and filaree (Erodium cicutarium) represented 13% and 26% of winter and spring sheep diets, respectively. The higher abundance of annual forbs and grasses on the flats can result from collection of water runoff from nearby slopes and/or lack of competing perennial vegetatioan for water (Martin 1975). Perennial grasses represented a higher percentage of the total vegetative cover on slopes (LMM) (1.8%) than on the flats (0.037%). Flats and gentle slopes were very green and lush in winter and spring 1983. Higher than normal winter and spring precipitation in 1983 (Fig. 2) may have increased the availabilitry of winter annuals on the flats.

Sheep fed among cattle on the flats on at least 2 occasions. Sheep would typically feed on the flats then move to the lower foothills to bed. However, 2 rams bedded on the flats where they had previously been feeding. Sheep on the flats often move among creosotebushes to feed on the thicker growths of annuals growing near these plants. These feeding forays often took sheep 50-100 m away from the nearby slopes. Sheep usually fed in tight groups, stayed in a small area, then moved a short distance to begin feeding again. All sheep quickly ran to steeper

ground when alarmed. Sheep moved back to higher slopes when winter annuals began to cure in April.

BB communities were considered preferred bighorn sheep habitat in Nevada because they had higher amounts of grass and were located at higher elevations (Bradley, 1964). Sheep did not feed heavily upon BB but instead used other forage species (Bradley, 1965). Sheep were seen feeding on BB by Bates and Workman (1983) and during this study. However, BB did not appear in the fecal analyses of this study.

Bighorn sheep occupied RIP communities only on a few occasions in summer. All sightings involved sheep moving downslope from LMM in the VRG to drink from the Virgin River. Sheep tracks were common along the Virgin River throughout the VRG. The absence of sheep sightings in RIP canyon bottoms may be due to limited visibility in these areas.

Sheep use PJ zones in Nevada where trees are not thick enough to impair visibility (McQuivey, 1978). In Arizona sheep avoided the PJ type. Other authors found little or no sheep use in forests due to limited visibility or lack of forage (Geist, 1971; Oldemeyer et al., 1971; Tilton and Willard, 1982; Elenowitz, 1983; Gionfriddo, 1985).

Seasonal variation of habitat use was limited. The Buck Springs ewes in Hatchet Canyon Gorge and ewes 877, 957 and 6 in Hedricks Canyon remained exclusively in the UMM type during the study. Hedricks ram 851 moved from LMM to UMM in fall 1982. He was followed by Hedricks ram 951 in spring 1983. Ewe 670 from Sullivans Canyon moved from UMM to LMM in summer 1982. Sheep in the VRG and Figure 4 and Hedricks Canyons used CBB and LMM in winter and spring and LMM, BB, and RIP in summer.

Aspect use did not differ signigicantly from availability for all groups examined ($G = 5.95$, $df = 3$, $p = 0.114$). Aspect use by sheep varied by season and sex. Ewe groups were located on south-facing

slopes more than north-facing slopes in winter ($p < 0.01$). There were no differences in aspect use by rams or mixed groups in winter. Ram and ewe groups were located on north-facing slopes more than south-facing slopes in spring ($p < 0.001$). Aspect use by mixed groups in spring and summer and by ram and ewe groups in summer were not significantly different.

Bighorn sheep feeding on south-facing slopes in winter may take advantage of earlier winter annual growth on the dry, warmer slopes (Went, 1949, Tilton and Willard, 1982). As spring progresses and temperatures increase, mesic, north-facing slopes have more lush growths of annuals than south-facing slopes. When winter annuals are cured during summer, there may not be an advantage to feeding on north as opposed to south-facing slopes. Higher abundance of forbs and grasses are expected on the more mesic north-facing slopes (Beatley, 1974). Vegetation transects on north and south-facing slopes in the LMM type showed little difference in major over and understory vegetation. Grasses represented 3.6% of total vegetative cover on north-facing slopes and 2.1% on south-facing slopes.

Slope use differed significantly from availability ($G = 73.97$, $df = 5$, $p = 0.001$). All groups examined preferred slopes greater than 60% (Table 4). Slopes less than 60% were used less or in the same proportion to availability. Virgin Mountain sheep prefer steeper slopes than sheep studied by Elenowitz (1983) and Gionfriddo (1985). Slopes greater than 50% were only 1.0% (Elenowitz, 1983) and 10.0% (Gionfriddo, 1985) of these study areas. In the Virgin Mountains, slopes of 61-80% and >81% represented 14.1% and 23.5% of the study area respectively. Higher use of steep slopes by sheep may result from the high

availability of these slopes in heavily used areas such as the VRG and Hatchet Canyon Gorge (Fig. 1). Steep slopes offer escape cover; sheep prefer areas in close proximity to escape cover (Shannon et al., 1975; Holl, 1982; Tilton and Willard, 1982). There were no significant differences in slope use by season or sex in this study. Mean slope use values for winter, spring, and summer were 77.1%, 76.1%, and 77.8%, respectively for all sheep.

Elevation use differed significantly from availability ($G = 11.85$, $df = 5$, $P = 0.037$). The only preferences for an elevational range were exhibited by ewe groups for elevations between 1,250 and 1,453 m and mixed groups for elevations less than 844 m. All other elevational ranges were used in lower or in the same proportion as availability (Table 5). The preference by ewe groups for elevations between 1,250 and 1,453 m may be due to the high use of the Hatchet Canyon Gorge by 5 Buck Springs ewes (010, 330, 610, 30, and 36). These ewes were found exclusively in this area at higher elevations.

There was little variation in elevation use seasonally or between ram, ewe, and mixed groups of sheep. Ram groups used higher elevations than mixed groups in summer ($P = 0.021$); ewes used higher elevations than mixed groups in spring ($P = 0.031$). Groups with lambs did not seek higher elevations than those without lambs in spring or summer. However, ewe groups with lambs used higher elevations than mixed groups with lambs ($P = 0.000$). There were no differences in elevation use between winter, spring, or summer for ram and ewe groups. Mixed groups used higher elevations in spring than winter ($P = 0.000$). Although not significantly different, elevation use means for ram groups increased

from winter ($\bar{X}$ = 87.8 m) to spring ($\bar{X}$ = 140.2 m) to summer ($\bar{X}$ = 222.5 m). These mean values were not significantly different due to the high sample variance.

Forage Selection.--Fifty-six plant taxa were identified in bighorn sheep diets in the Virgin Mountains during late winter and spring 1983 and the summers of 1982 and 1983 (18 shrub species, 25 forb species, 11 grass species, and 2 succulent species) (Appendix 2). Total diet consisted of 53.5% forbs, 27.3% browse, 16.6% grasses, and 2.4% succulents. When the diet was examined on a seasonal basis for all sheep and for rams and ewes, forbs made up the highest proportion of the diet during all seasons except summer 1983 when browse was 47.5% of the diet, forbs 38.4%, grasses 10.7% and succulents 0.6%. Fewer plant taxa were found in the fecal analysis of summer 1983 than 1982 (25 and 41, respectively); however, fewer fecal samples were collected in 1983 over a shorter collection period. Browse use exceeded forb use in summer 1983 due to the heavy use of ratany (30.6% of total summer diet). When the summers of 1982 and 1983 are combined, forbs make up a higher proportion of the diet (50.6%) than browse (25.1%), grasses (22.7%), or succulents (4.5%).

Seventeen plant taxa were considered major food items in sheep diets ()5% of the diet) (Table 6). Of these plants, 3 were browse species, 8 were forbs, 5 were grasses, and 1 was a succulent. Globe mallow (Sphaeralcea spp.) was a major forb species in winter, spring, and summer consisting of 8.7%, 9.7%, and 23.6% of the diet, respectively. Sandsage (Artemesia ludoviciana) was used heavily in summer. Other forb species were used heavily in winter and/or spring (Table 6).

Winter fat (Ceratoides lanata) was a major browse species in the winter and spring for all sheep and ewes and in spring and summer for rams. Ephedra was used heavily by all sheep in summer. Ratany (Krameria spp.) was used heavily by rams in both spring and summer (Table 6).

Grasses made up a higher percentage of ram than ewe diets in winter and spring but were higher in ewe diets in summer (Table 6). Only grama (Bouteloua spp.) made up at least 5% of ewe diets; it was used heavily in summer by ewes. Four grasses, needlegrass (Stipa spp.), red brome, big galleta (Hilaria rigida), and Mediterranean grass (Schismus barbatus), were major items in ram diets. Use of each grass species varied during winter, spring, and summer. The annual species, red brome and Mediterranean grass, were used most heavily in spring after the winter rains. These species were cured in summer and thereafter received little use. Needlegrass was used most heavily in winter; big galleta was used most in summer.

Barrel cactus (Ferocactus acanthodes) became a major part of ram diets in summer. Barrel cactus, cholla, and prickly pear (Opuntia spp.) were used increasingly from spring to summer (Fig. 3). Barrel cactus appeared only in the summer 1982 diets. Barrel cacti hollowed out by sheep were often found in areas with little or no available water. Barrel cactus was used heavily in the enclosure while water tanks were not (J. Morgart, pers. comm.). The proportion of succulents in the diet may be underestimated because they may fail to appear in the fecal analysis.

The proportion of forage classes used by Virgin Mountain sheep differed from studies by Barrett (1964), Elenowitz (1983), and Morgart et al. (1981). Browse dominated diets in winter, spring, and summer in

southern New Mexico (Elenowitz, 1983), whereas grasses dominated diets in winter, spring, and summer on the Desert Game Range in southern Nevada (Barrett, 1964). In the Virgin Mountain sheep enclosure, forage class use fluctuated each season (Morgart et al., 1981). No one forage class dominated the diet during all seasons.

Calculated overlap of ram and ewe diets were significant with the exception of grasses in winter (0.516) and summer (0.261) and succulents in summer (0.506). Seasonally there was greater overlap in ewe diets between winter and spring than between spring and summer. There was no significant overlap between spring and summer for browse (0.380), grass (0.410), forb (0.180), or succulent (0.267) use. Succulents did not appear in winter diets. The only overlap in ram diets occurred for forbs between winter and spring (0.736) and browse between spring and summer (0.732). Such measures in dietary overlap are important in studying interspecific competition (Alcoze and Zimmerman, 1973).

The Simpson's diversity index for diet diversity was highest for spring diets and lowest for winter diets of rams, ewes, and all sheep. The number of forage species in the diets was highest in summer and lowest in winter for rams, ewes, and all sheep. Summer diets had lower diversity indices than spring diets because fewer forage species represented a larger percentage of the total diet in summer than in spring. Higher diversity indices for the spring diets could result from more available annuals following winter rains. When these forbs and grasses cure in late spring and early summer, they decrease in the diet. Additional browse and succulent species replace them, but the majority of the summer diet consists of fewer species such as ratany, globe mallow, and sandsage.

Productivity.--Eleven lambs were seen during the late spring and summer of 1982 (Appendix 3). Three lambs were not observed until August when their mothers were located. It is possible that more lambs were born this year and died before field work began. One dead lamb was found on 10 August in Hedricks Canyon. Three ewes had lambs earlier in the area. However, in January 1983, all 3 ewes were seen with the previous season's lambs. Between January and February 1983, 10 of the 11 1982 lambs were seen.

In 1983, 18 lambs were born, with 3 in the enclosure. At least 6 of the 11 ewes that had lambs in 1982 gave birth in 1983. The first 1983 lamb was seen on 3 March in the VRG and was 1-2 weeks old. Its estimated conception date is during the first 2 weeks of September 1982, based on a 180-day gestation period (Turner and Hansen 1980). The last lamb (Buck Spring ewe 610,s) was seen on 10 June in Hatchet Canyon Gorge and was at most 22 days old. Its conception date would have been during late November to early December 1982. These sheep display the broad breeding and lambing seasons shown by other desert bighorn sheep populations (Bunnell, 1982; Thompson and Turner, 1982).

Four of the 1983 lambs were born in the VRG. However, only 1 of the ewes had a functioning radio collar. Ewe 830 from Sullivans Canyon was located aerially on the high rugged cliffs of the narrows in the VRG (T41N, R14W, section 32 SW 1/4 W 1/2) from 14-23 April 1983 (Fig. 3). She was observed with a lamb on the lower slopes of the same area on 25 April. Ewe 720 from Sullivans Canyon was aerially located on the same cliffs on 20 April and 5 May 1982. She was seen on 17 June with a lamb. Ewe 36 from Buck Springs disappeared in this area from 30 April until 9 June 1982 when she was found with a very small lamb. The vegetation here is a mixture of LMM and BB.

Ewes 820 and 19 from Sullivans Canyon lambed on the cliff faces between Grey Points and Purgatory Canyon between 27 March and 11 April 1983 (Fig. 1). The vegetation in this area is LMM on the slopes and BB on the flat mountain tops.

Hedricks Canyon ewes (877, 957, and 6) lambed in the rugged mountains between Figure 4 and Hedricks Canyons (Fig. 1). This area is extremely rugged and almost inaccessible on foot. Most of this area consists of UMM. These ewes were only found on the few occasions that they moved down into Hedricks Canyon. Ewe 877 and 957's collars worked sporadically, making it difficult to determine exactly when their lambs were born. This area is approximately 2.8 km from tne enclosure and is the closest that I recorded any ewes coming to the enclosure to lamb. Whether any of the enclosure-released ewes would have returned to the enclosure to lamb cannot be determined. The fence is a barrier, but the enclosure is not totally impenetrable. Ewe 931 and an unmarked ram, both born in the enclosure, reentered, and ram 53, released into the enclosure on 4 May 1982, was seen outside on 13 March 1983 with four direct-released rams.

Five Buck Springs ewes (610, 010, 330, 30, and 34) gave birth to lambs in the 1983 season on the cliff face at the entrance of Hatchet Canyon Gorge (T38N, R15W, sec 5) (Fig. 1). The vegetation in this area consists of UMM, BB, and PJ. All lambing areas are located in the more rugged portions of the Virgin Mountains.

The mean date of birth of the 1983 season was 4 April (SE = 0.8 days), calculated by the method described by Caughley (1977). This is based on estimated birth dates.

Mortality.--Sixteen mortalities were documented from November 1981 to August 1983 (Appendix 4). The Buck Springs direct-release group suffered the highest number of mortalities. Pneumonia and lion predation may have been the main causes of death. Two Hedricks sheep were seen wheezing, coughing, and in emaciated condition before they were found dead. A yearling ram was found dead at the bottom of a ravine without external injuries to indicate predation. Ram 981's mortality sensor failed to go off until at least a week after he was dead. The carcass was in too poor condition to perform a necropsy. Bones and pieces of the carcass were scattered about in a small ravine.

Only 2 mortalities were found in 1983. Hedricks ewe 891 was found high in Figure 4 Canyon in March. Her remains were scattered when found and cause of death could not be determined. Sullivan ram 12 was found in the VRG near the entrance of Sullivans Canyon by kyakers in June. He had been dead for a long time; the entire skeleton was nearly stripped of flesh.

Ewe 670 from Sullivans Canyon was found dead near Grey Points and ram 951 from Hedricks Canyon was found dead in Elbow Canyon after this study (T. Soderquist, pers. comm.).

Sheep Use in the Virgin River Gorge.--The Virgin and Beaver Dam Mountains are separated by the VRG. Twenty-five of the released sheep, regardless of release site, have used the VRG. The VRG is the most rugged portion of the study area; slopes of 40% and nearly vertical cliffs are common. There are 3 vegetation types in the VRG: 1) RIP with thick groves of salt cedar and desert willow, 2) LMM on the lower slopes, and 3) BB on the higher elevations. The most striking feature of the VRG is Interstate 15 running between St. George, Utah and Las Vegas, Nevada. It is a four lane highway divided by a 1.5-m iron mesh

and concrete median. Four bridges cross the Virgin River at three locations.

The majority of the sheep using the VRG are from Sullivans Canyon. These sheep were released at the mouth of Sullivans Canyon which lies in the eastern portion of the VRG. Many of the Hedricks and a few Buck Springs sheep also spend time in the VRG. Sheep use seemed heaviest during the winter and summer. Sheep moved up to the higher BB slopes of the Beaver Dam Mountains overlooking the gorge during late spring-early summer. Water sources at these elevations were not located or reported (Morgart et al., 1981). This may explain why sheep move down into the gorge along the river in the summer. Sheep tracks were common along the river at this time. On 3 occasions sheep moved downslope to the river to drink at midday. Sheep also used lower slopes heavily during winter when they are lush with annual growth. Groups of sheep were often observed in the gorge while driving along the interstate. On 4 occasions sheep were located as people were watching and photographing them. Sheep were seen feeding along the shoulder of the interstate on two occasions. Buck Springs ram 210 was seen in the middle of the interstate and caused cars and trucks to stop. He finally moved when a driver stepped out of his truck. Ram 210 was also seen feeding along the shoulder by an Arizona Highway Department worker. Another worker reported seeing sheep jumping the 1.5-m median dividing the interstate.

To date, no sheep have been killed on Interstate 15. Two mule deer does (Odocoileus hemionus) were killed in 1983. Deer kills are not uncommon in the VRG, especially near the entrance of Sullivans Canyon (M. Barnett, pers. comm.) Deer crossing signs were erected at both ends of the gorge during the fall of 1983 to warn motorists.

Despite the presence of the interstate, median, and river, sheep cross from one side of the gorge to the other. Twenty-two crossings have been documented from aerial and ground locations. Fourteen crossings were made by rams and 7 by ewes (Appendix 5). Most occurred from January to April when the Virgin River was deep with snow melt from Utah. In order to cross from the Virgin to the Beaver Dam Mountains, sheep must cross the river, a barb wire fence, the interstate, and the median. The sheep usually use two alternate routes, through a culvert and under the bridges. There is a 2.5-m culvert that passes under the barb wire fence and interstate and opens at the foot of the Beaver Dam Mountains. Sheep tracks have been found leading into this culvert. Sheep use caves as cover during the summer (Simmons, 1981) and culverts may offer similar protection.

Sheep can cross under the interstate at each of the four bridges in the gorge. On one occasion a young ram crossed under a bridge. Interviews with highway department personnel and the presence of pawed areas and pellets show that sheep bed under the bridges during summer. A ewe and her lamb used one bridge on several occasions during spring 1983. At one area the river makes a sharp turn and the interstate crosses two points approximately 50 m apart. Hedricks ewe 900 and her lamb with two other sheep were seen on the point between the bridges on two occasions, and reports of two other sightings were made (L. D. Walker, pers. comm.). In order to get on the point, sheep must pass under the bridges or cross the interstate. This point is cut off from escape cover by the river and interstate and has little vegetation growing on it.

CONCLUSIONS.--Desert bighorn transplants have taken place in the winter (Jense et al., 1979; Kilpatric, 1979; McCutchen, 1979; Ravey and

Schmidt, 1981), summer (McQuivey, 1981; McQuivey and Pulliam, 1981; Elenowitz, 1982), and fall (deVos et al., 1981). The Virgin Mountain sheep were direct-released in November and enclosure-released in January. Dodd (1983) suggested releasing sheep in early spring, prior to the lambing season, to imprint ewes on lambing sites and to reduce post-release movements. Most Virgin Mountain ewes remained close to their release sites during the first spring. A few direct-released sheep (ewes 670, 700, 820, and 14 from Sullivans Canyon) moved greater than 8 km after release and lambed. This could have been a result of initial exploratory movements, gravid restlessness (searching for suitable lambing sites) (Geist, 1971), or a fall release when movements are greater than in the spring (Dodd, 1983).

Three release sites resulted in a wide distribution of reintroduced sheep in the Virgin Mountains. There seems to be little probability that sheep will concentrate in areas to a point of limiting population growth (Hansen, 1971; Dodd, 1983).

Evaluating which release technique was more successful in the Virgin Mountains is difficult. Sheep were released from the enclosure in January 1982, whereas the two direct releases took place in November 1981. Sheep movements after release were measured from aerial locations. Frequency of flights was inconsistent , ranging from 1-4 weeks apart. Flights were initially 7-10 days apart after the two direct releases. Following the enclosure release, flight intervals increased to 10-30 days for the initial 5 locations. Whether the differences between movements of the two groups of sheep were a result of the release technique, season of release, or location intervals cannot be determined.

One direct release, Sullivans Canyon, had the highest survivorship of radio collared animals (100%) and produced the highest number of lambs (12) for the 2 seasons. Sullivans sheep dispersed widely, using more areas than the other 2 groups. However, the Buck Springs direct release had the lowest survivorship of radio collared animals (47%), and produced only 7 lambs in 2 seasons. The Hedricks enclosure release is difficult to evaluate. It had a survivorship of 50% for radio collared animals and produced only 7 lambs in 2 seasons. Hedricks rams did disperse to different parts of the range, but not to the same degree as the Sullivan sheep. Most of the Hedricks radio collars did not operate or worked intermittently throughout most of the study. Ram 920's collar did not work during the summer of 1982 and he was not seen afterwards. Little data were collected on Hedricks ewes 877 and 957 because their collars worked very sporadically.

The enclosure release and the Buck Springs release were almost identical in mortality and productivity. The high mortalities among Buck Springs sheep may have resulted from pneumonia brought on by stress from prolonged handling and unseasonally warm weather during release (J. Morgart, pers. comm.). The Sullivan release was by far the most successful despite the extreme exploratory behavior exhibited by individuals. Though none were lost by predation or by dispersing from the area and not returning, these possibilities exist with direct-released sheep. The seriousness of this problem may decrease with the increasing use of drop nets. Social units of sheep can be baited, captured, and released. These units may keep their cohesiveness and remain together after release (Ravey and Schmidt, 1981). These groups would explore together and thus utilize more of the range (Geist, 1967, 1971). When sheep become familiar with a larger area, they have the

ability to move to equivalent suitable habitat rather than to marginal habitat when pressed by drought, man, or naturally caused disturbances (Elenowitz, 1983).

High productivity and survivorship of lambs in 1982 and 1983 has compensated for the high initial mortality of released sheep from pneumonia and mountain lion predation. The population as of July 1983 has approached the original number first released. Ground work in the Virgin Mountains to determine the 1984 lamb crop would be difficult due to the decreasing number of functioning radio collars.

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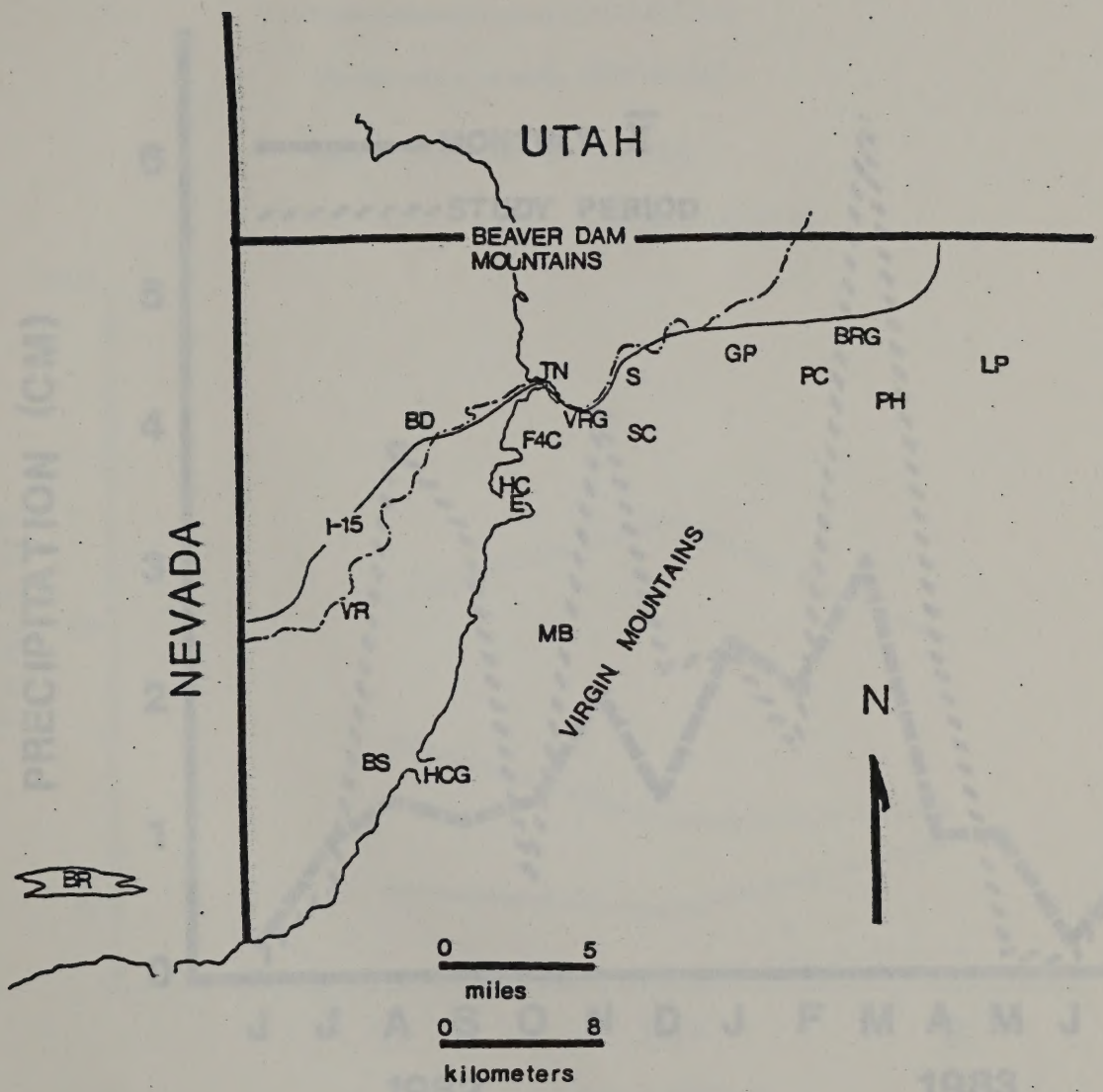

Fig. 1. Virgin Mountains, Arizona and surrounding areas. BD = Beaver Dam, AZ; BR = Bunkerville Ridge; BRG = Black Rock Gulch; BS = Buck Springs release site; E = enclosure; F4C = Figure 4 Canyon; GP = Grey Points; HC = Hedricks Canyon; HCG = Hatchet Canyon Gorge; LP = Lizard Point; MB = Mt. Bangs; PC = Purgatory Canyon; PH = Pocket Hill; S = Sullivans Canyon; TN = The Narrows; VR = Virgin River; VRG = Virgin River Gorge.

UTAH
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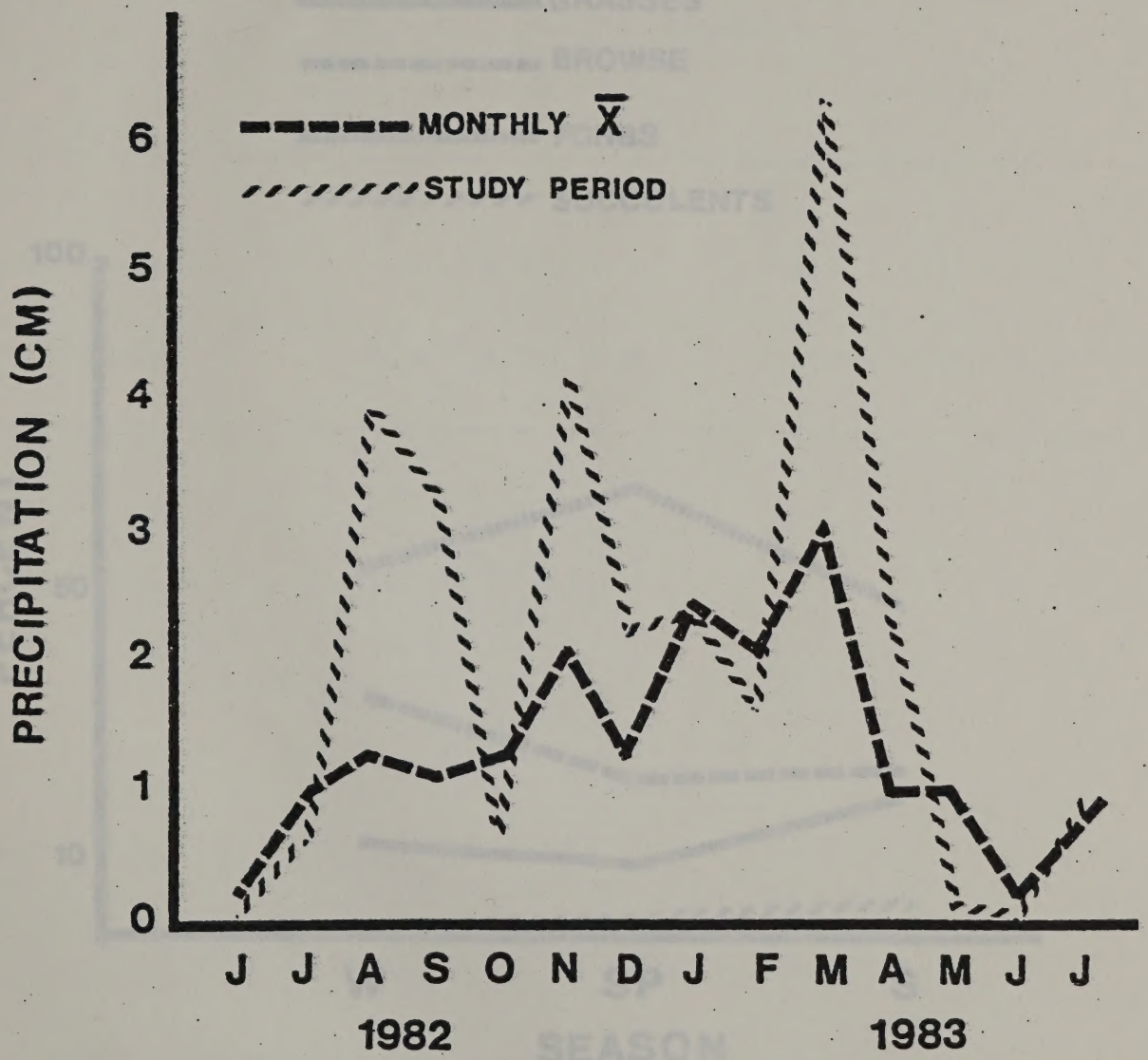

Fig. 2. Study period and mean monthly precipitation in the Virgin Mountains, Arizona.

PRECIPITATION (CM)
0
1
2
3
4
5
6
J J A S O N D J F M A M J J
1982
1983

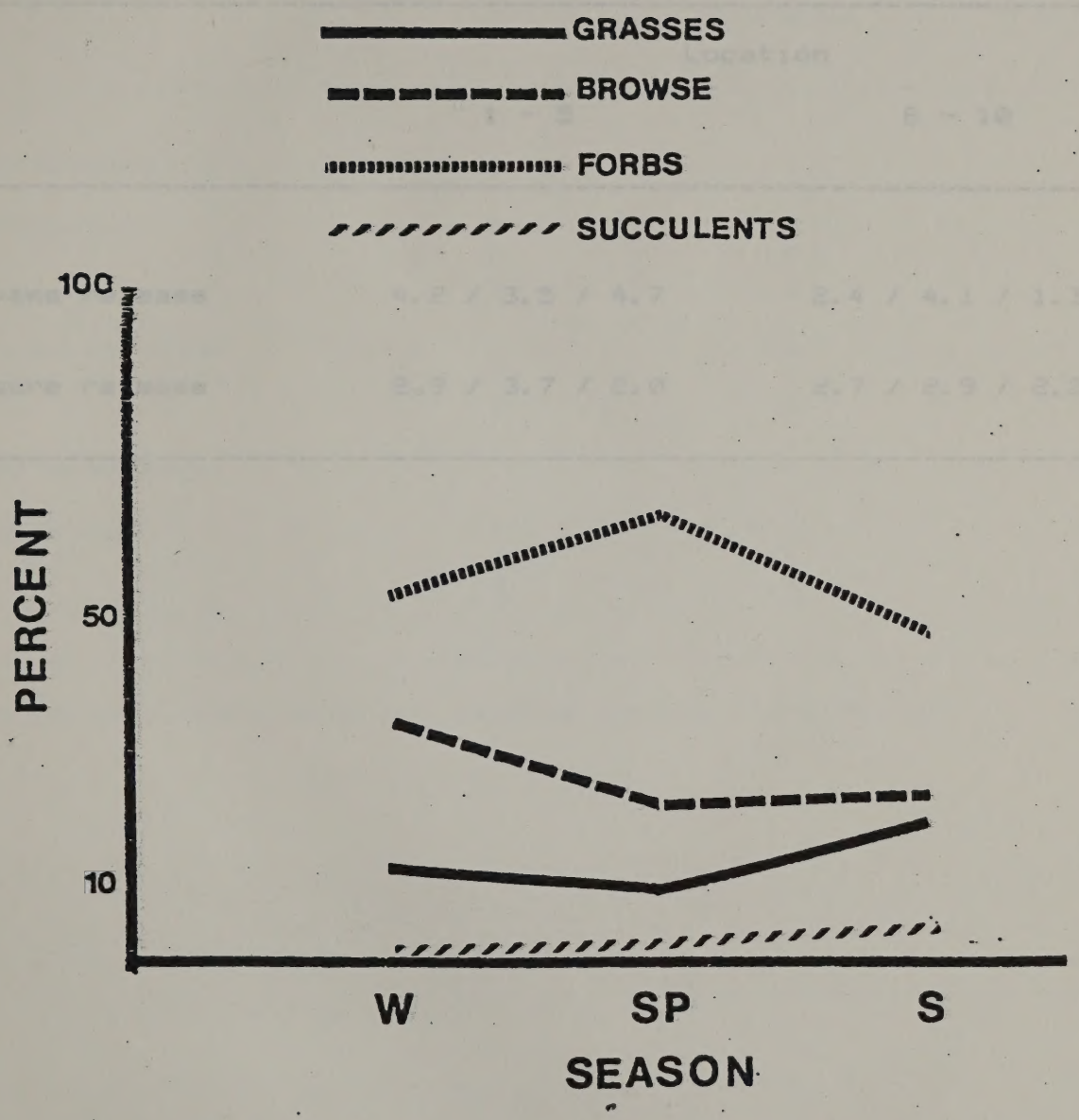

Fig. 3. Seasonal proportions of browse, grasses, forbs, and succulents in bighorn sheep diets in the Virgin Mountains, Arizona, 1982-1983.

Fig. 3. Seasonal proportions of browse, grasses, forbs, and succulents in Bighorn sheep diets in the Virgin Mountains, Arizona, 1982-1983.

Table 1. $\bar{X}$ straight line distances (km) moved by all sheep/rams/ewes during the first 5 locations and locations 6-10 in the Virgin Mountains, Arizona, 1981-1982.

Sheep	Location 1 - 5	Location 6 - 10
Sullivans release	4.2 / 3.5 / 4.7	2.4 / 4.1 / 1.3
Enclosure release	2.9 / 3.7 / 2.0	2.7 / 2.9 / 2.2

Table 2. Dispersal of released bighorn sheep in the Virgin Mountains, Arizona, 1981-1982.

	Flight #	# Groups	n = # sheep
Direct-Release			
Sullivans	1	8	10
	2	10	10
	3	8	10
Buck Springs[1]	1	8	10
	2	8	10
	4	5	10
Enclosure-Release			
Hedricks	1	3	12
	2	7	12
	3	10	12

[1] Buck Springs sheep were not located on the third flight.

Table 3. Habitat use by bighorn sheep in the Virgin Mountains, Arizona, 1982-1983.

Habitat type	Availability (%)	Use (%)	Use in relation[1] to availability
Disturbed	0.3	0.6 / 0 / 1.0 / 0[2]	= / = / = / =[3]
Creosotebush Flat	8.4	2.3 / 3.6 / 1.0 / 4.1	< / < / < / =
Riparian	3.1	0.8 / 0.6 / 1.0 / 0	< / = / = / =
Lower Mixed Mohave Desert Shrub	33.5	53.6 / 53.5 / 48.6 / 69.9	> / > / > / >
Upper Mixed Mohave Desert Shrub	38.4	30.3 / 28.1 / 36.3 / 13/7	< / < / + / <
Blackbrush	6.8	10.5 / 13.8 / 8.2 / 12/3	> / > / = / >
Pinyon-Juniper	9.6	2.3 / 0.6 / 3/8 / 0	< / < / < / <

[1] $p < 0.05$

[2] all sheep % / ram % / ewe % / mixed group %

[3] all sheep / rams / ewes / mixed groups

Table 3. Habitat use by bighorn sheep in the Virgin Mountains, Arizona, 1982-1983.

Habitat type	Availability (%)	Use (%)	Use in relation to availability
Disturbed	6.3	6.8	1.0
Creosotebush Flat	8.4	2.3	3.8
Riparian	3.1	0.8	1.0
Lower Mixed Mohave Desert Scrub	33.5	53.6	48.6
Upper Mixed Mohave Desert Scrub	28.4	30.3	28.1
Blackbrush	6.5	12.5	13.8
Pinyon-Juniper	9.8	5.3	6.5

1 $p < 0.05$.

2 all areas X \ res X \ use X \ mixed group X

3 all areas \ rems \ areas \ mixed groups

Table 4. Slope use by bighorn sheep in the Virgin Mountains, Arizona, 1982-1983.

Slope Class (%)	Availability (%)	Use (%)	Use in Relation[1] to availability
0-10	8.0	3.6 / 3.0 / 2.7 / 8.2[2]	< / < / < / =[3]
11-20	6.3	1.9 / 1.8 / 2.4 / 0	< / < / < / <
21-40	17.1	8.6 / 8.4 / 7.5 / 12.3	< / < / < / =
41-60	31.0	27.8 / 27.5 / 26.7 / 31.5	= / = / = / =
61-80	14.1	23.3 / 20.4 / 27.4 / 12.3	> / > / > / =
>81	23.5	34.8 / 38.9 / 33.2 / 35.6	> / > / > / >

[1] $p < 0.05$

[2] all sheep % / ram % / ewe % / mixed group %

[3] all sheep / rams / ewes / mixed groups

Table 5. Elevation use by bighorn sheep in the Virgin Mountains, Arizona, 1982-1983.

Elevation (m)	Availability (%)	Use (%)	Use in Relation[1] to availability
<844	16.8	20.7 / 24.3 / 19.2 / 41.1[2]	= / = / = / >[3]
845-1048	21.5	22.9 / 27 / 20.9 / 24.7	= / = / = / =
1049-1249	22.3	22.0 / 24.3 / 17.8 / 24.7	= / = / = / =
1250-1453	19.6	20.9 / 13.5 / 27.1 / 5.5	= / = / > / <
1454-1658	15.1	11.1 / 10.8 / 12.7 / 4.1	< / = / = / <
>1659	4.8	2.4 / 0 / 2.4 / 0	< / = / = / =

[1] $p < 0.05$

[2] all sheep % / ram % / ewe % / mixed group %

[3] all sheep / rams / ewes / mixed groups

Table 6. Major forage species in bighorn sheep diets on a seasonal basis in the Virgin Mountains, Arizona, 1982-1983.

W = winter, Sp = Spring, Su = Summer.

Plant Species	All Sheep	Rams	Ewes
Ceratoides lanata	W, Sp	W, Sp, Su	W, Sp
Ephedra spp.	Su	Su	Su
Krameria spp.	Su	Sp, Su	Su
Artemesia ludoviciana	Su	Su	Su
Astragalus spp.	Sp	Sp	Sp
Eriogonum inflatum	W, Sp	W, Sp	S, Sp
Erodium cicutarium	Sp	Sp	Sp
Notholaena paryii	W		W, Su
Plantago insularis	W, Sp	W, Sp	W, Sp
Sphaeralcea spp.	W, Sp, Su	W, Sp, Su	W, Sp, Su
Borage spp.	Sp	Sp	Sp
Bouteloua spp.	Su		Su
Bromus rubens		Sp	
Hilaria rigida		Su	
Schismus barbatus		Sp	
Stipa spp.		W	
Ferocacatus acanthodes		Su	

Table 6. Major forage species in pinyon-sheep diets on a seasonal basis in the Virgin Mountains, Arizona, 1982-1983.

W = Winter, Sp = Spring, Su = Summer.

Plant Species	All Sheep	Rams	Ewes
Coleogyne ramosa	W, Sp	W, Sp, Su	W, Sp
Eriogonum spp.	Su	Su	Su
Artemisia spp.	Su	Sp, Su	Su
Ambrosia dumosa	Su	Su	Su
Opuntia spp.	Sp	Sp	Sp
Stipa speciosa	W, Sp	W, Sp	W, Sp
Stipa hymenoides	Sp	Sp	Sp
Poa secunda	W		W, Su
Hilaria rigida	W, Sp	W, Sp	W, Sp
Larrea tridentata	W, Sp, Su	W, Sp, Su	W, Sp, Su
Bouteloua spp.	Sp	Sp	Sp
Bouteloua eriopoda	Su		Su
Erioneuron pilosum		Sp	
Aristida glauca		Su	
Sporobolus cryptandrus		Sp	
Stipa spp.		W	
Leptochloa dubia		Su	

APPENDIX 1

STATUS OF REINTRODUCED BIGHORN SHEEP IN THE

VIRGIN MOUNTAINS, ARIZONA, 31 JULY 1983

Ear Tag #	Frequency	Age	Sex	Comments
Sullivans Canyon				
0	149.830	5 1/2	F	Observed with lamb
1	149.720	3 1/2	F	Observed
2	149.870	4 1/2	M	Observed in Nevada
3	149.810	4 1/2	M	Observed
4	149.700	4 1/2	F	Observed
5	149.840	3	M	Observed
6	149.820	5 1/2	F	Observed with lamb
7	149.800	3 1/2	F	Observed
8	149.670	5 1/2	F	Observed with lamb
11	149.780	3	M	Observed, non-funct. collar
9	cloth	4 1/2	F	Observed
12	cloth	6	M	Dead in Sullivans Canyon
13	cloth	4 1/2	F	Observed
14	cloth	4 1/2	F	Not observed
15	cloth	4 1/2	F	Not observed
16	cloth	7 1/2	F	Observed with yearling male
17	cloth	8	M	Dead in Hatchet Canyon
18	cloth	3 1/2	F	Observed with lamb
19	cloth	3 1/2	F	Observed with lamb
20	cloth	7	M	Observed
Buck Springs				
40	149.080	5	F	Dead 1982
41	149.010	3 1/2	F	Observed with lamb
42	149.610	3 1/2	F	Observed with lamb
43	149.450	6	F	Dead 1982
44	149.490	3	M	Dead 1982
45	149.020	4	F	Dead 1982
46	149.330	5 1/2	F	Observed with lamb
47	149.210	5 1/2	M	Observed
49	149.540	5	M	Dead 1982
51	149.090	3	M	Dead 1982

Ear Tag #	Frequency	Age	Sex	Comments
40	cloth	4 1/2	F	Observed with lamb
31	cloth	5 1/2	F	Not observed
32	cloth	6	F	Dead 1982
33	cloth	5 1/2	F	Not observed
34	cloth	5 1/2	F	Observed with lamb
35	cloth	3 1/2	F	Not observed
36	cloth	3 1/2	F	Observed with lamb
37	cloth	5 1/2	F	Not observed
38	cloth	3	M	Observed
39	cloth	3	M	Dead 1981
50	cloth	3 1/2	M	Not observed
Hedricks Canyon				
1	149.911	4 1/2	F	Dead N Fig. 4 Canyon, 1981
4	148.957	7	F	Observed with lamb, collar works intermittently
5	148.920	5 1/2	M	Not observed, non-funct. collar
6	none	5 1/2	F	Observed with lamb
8	149.900	6	F	Observed with lamb, non-funct. collar
9	148.851	7	M	Observed, non-funct. collar
12	149.951	5	M	Observed
14	148.877	7 1/2	F	Observed with lamb, collar works intermittently
17	149.891	3	F	Dead in Fig. 4 Canyon
18	149.971	2 1/2	F	Dead in 1982
20	149.880	3 1/2	M	Observed
25	149.981	3	M	Dead 1982
Unmarked		2 1/2	M	Observed
Unmarked		2 1/2	M	Observed
Unmarked		2 1/2	M	Observed
Unmarked		2 1/2	M	Observed
Unmarked		2 1/2	M	Dead 1982
Unmarked		2	F	Observed
Unmarked		2	F	Not observed

Ear Tag #	Frequency	Age	Sex	Comments
Sheep in Enclosure				
3	149.961	7	F	
7	148.903	4 1/2	F	Non-funct. collar
13	148.973	5 1/2	F	Non-funct. collar
21	149.941	2 1/2	F	
24	149.931	3 1/2	F	Released Jan 82, returned to enclosure
52	149.971	7	M	Put into enclosure 4 May 82
53	none	5 1/2	M	Put into enclosure 4 May 82 escaped Spring 83
Unmarked		1 1/2		
Unmarked		1 1/2		
Unmarked		2 1/2	M	Released Jan 82, returned to enclosure

3 lambs were seen in the enclosure March-April 83 by wildlife manager Todd Soderquist.

APPENDIX 2

FORAGE SPECIES PRESENT IN BIGHORN SHEEP DIETS IN THE VIRGIN MOUNTAINS, ARIZONA, 1982-1983

BROWSE

Ambrosia dumosa
Artemesia tridentata
Atriplex canescens
Brickellia atractyloides
Ceratoides lanata
Ceanothus greggii
Encelia frutescens
Ephedra spp.
Eriogonum fasiculatum
Eriogonum wrightii
Galium spp.
Jansia gracilus
Krameria spp.
Larrea tridentata
Prunus fasiculata
Quercus turbinella
Rhus trilobata
Salazeria mexicana

FORBS

Anemone tuberosa
Arabis perennans
Artemesia ludoviciana
Astragulus spp.
Baileya multiradiata
Borage spp.
Camissonia multijuga
Castilleja chromosa
Descurainia sophia
Ditaxis lanceolata
Erigeron spp.
Eriogonum inflatum
Eriophyllum wallacei
Eriodium cicutarium
Lesquerella gordoni
Lotus spp.
Lupinus spp.
Notholaena parryii
Pelleae longimucronata
Perezia spp.
Phaecelia fremontii
Plantago insularis
Sphaeralcea spp.
Tidestromia lanuginosa

GRASSES

Andropogon spp.
Aristida purpurea
Bouteloua spp.
Bromus rubens
Erioneuron pulchellus
Hilaria rigida
Muhlenbergia porteri
Oryzopsis hymenoides
Poa spp.
Schizmus barbatus
Sporobolus spp.
Stipa spp.

SUCCULENTS

Ferocactus acanthodes
Opuntia spp.

APPENDIX 3

BIGHORN EWES LAMBING IN THE VIRGIN MOUNTAINS, ARIZONA, 1982-1983

1982 Lambing Season

Sullivans	Hedricks	Buck Springs
670	891	010
700	957	
720	6	
800		
820		
13		
14		

1983 Lambing Season

Sullivans	Hedricks	Buck Springs
670	877	010
820	900	330
830	957	610
18	6	30
19		34

APPENDIX 4

BIGHORN SHEEP MORTALITIES IN THE VIRGIN MOUNTAINS, ARIZONA,

NOVEMBER 1981 - JULY 1983

Sheep #[1]	Age(years)	Sex	Cause of Death	Date Recovered
B 39	2	M	Unknown	22 Jan 82
B 080	4	F	Possible predation	22 Jan 82
B 490	2	M	Pneumonia	22 Jan 82
B 540	4	M	Pneumonia	14 Feb 82
S 17	7	M	Pneumonia	14 Feb 82
B 090	2	M	Possible predation	31 Mar 82
H 971	1	F	Possible predation	13 Apr 82
H 911	3 1/2	F	Predation	30 May 82
B 450	5	F	Pneumonia or predation	3 Jun 82
B 020	3	F	Predation	1 Jul 82
B 32	5	F	Possible predation	1 Jul 82
H yearling	1 1/2	M	Possible pneumonia	21 Jul 82
H 981	2 1/2	M	Pneumonia or predation	22 Jul 82
lamb		M	Unknown	10 Aug 82
H 891	2 1/2	F	Possible predation	
S 12	5 1/2	M	Unknown	

[1] S = Sullivans, B = Buck Springs, H = Hedricks

APPENDIX 5

BIGHORN SHEEP CROSSINGS OF THE VIRGIN RIVER GORGE,

ARIZONA, 1982 - 1983

Sheep #[1]	Sex	Date	Virgin to Beaver Dam Mts.	Beaver Dam to Virgin Mts.
S 700	F	28 Jul-2Aug 82	X	
S 720	F	Aug 82-Jan 83	X	
S 780	M	13 Feb-26 Feb 82	X	
		31 Mar-13 Apr 82		X
		Aug 82-Jan 83	X	
		20 Jan-12 Feb 83		X
		12 Feb-22 Feb 83	X	
S 800	F	27 May-12 Jun 82	X	
		12 Jun-23 Jun 82		X
		15 Jan-19 Jan 83	X	
S 810	M	13 Feb-26 Feb 82	X	
		31 Mar-13 Apr 82		X
		27 May-12 Jun 82	X	
		23 Jun- 5 Jul 82		X
		12 Jul-21 Jul 82	X	
S 830	F	26 Feb-23 Mar 82	X	
		13 Apr-20 Apr 82		X
B 210	M	12 Feb-22 Feb 83	X	
H 880	M	20 May-12 Jun 82	X	
		12 Jun-21 Jun 82		X
		2 Apr-14 Apr 83	X	
		6 Jun-12 Jun 83		X

[1] S = Sullivans, B = Buck Springs, H = Hedricks